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Impacts of Greenhouse Gas Emission Regulations on the U.S. Sugar Industry

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ABSTRACT

The objective of this study is to evaluate the changes in U.S. sugar production and Greenhouse Gas (GHG) emissions from the sugar industry if the United States regulates GHG emissions from domestic sugar processing facilities. A spatial equilibrium model is developed to optimize sugar production in the United States under a base scenario and three different levels of CO_2e taxes or prices of carbon offsets. This research focuses on U.S. sugar production, both beet and cane sugar. In the model the United States is divided into 6 beet growing regions and 4 cane growing regions. The model also includes Mexico as a domestic sugar growing region as Mexico has the ability to export unlimited amount of sugar into the United States under NAFTA. A rest of the world region is included because the United States imports sugar from about 40 different nations.

The results indicate that sugar production by the U.S. beet sugar industry will decrease substantially if carbon emissions are taxed in the United States. Production in the U.S. cane industry will also decrease, but only slightly. Sugar imports from Mexico will increase but the majority of the imported sugar will come from other countries as Mexico's ability to increase sugar production is limited. GHG emissions will decrease, but only slightly, because the GHG emissions that are reduced in the United States are replaced by GHG emission in other nations as U.S. sugar production is shipped overseas. However the impacts on the U.S. sugar industry would be substantial with GHG emission regulations.

Keywords: GHG emissions, CO_2e, Sugar, spatial equilibrium model, carbon tax, cap and trade.

HIGHLIGHTS

Three scenarios were developed because future CO_2e regulations and/or taxes are unknown. A base scenario was developed to replicate current U.S. sugar production and imports. The three other models that are included are a $10 per ton tax on CO_2e, a $20 per ton tax on CO_2e, and finally, a $30 per ton tax on CO_2e. Under a cap and trade system it is assumed that, the taxes are equivalent to the price of carbon offsets.

The beet sugar industry uses coal as a main energy source, while the cane sugar industry uses natural gas and bagasse as main energy sources. The U.S. beet sugar industry emits about 1.1 metric ton of CO_2e per ton of sugar, while the U.S. cane sugar industry emits about 0.6 metric ton of CO_2e per ton of sugar. Because most beetsugar processing facilities do not have access to natural gas and the price of natural gas is significantly higher than coal, switching from coal to natural gas is currently infeasible. Carbon emissions in the sugar industry in other countries are higher than those in the U.S. cane industry, but lower than those in the U.S. beet industry (0.893 tons CO_2e /ton of sugar for Mexico and 0.692 tons CO_2e /ton of sugar for other countries).

Under model 2, with a carbon tax (price) of $10 per ton of CO_2e, sugar production by the U.S. beet sugar industry fell 17% while the cane industry fell 3%. Imports from Mexico increased 43% and imports from other countries increased 50%.

Under models 3 and 4, with a carbon tax (price) of $20 per ton of CO_2e and $30 per ton of CO_2e, respectively, production by the U.S. beet sugar industry fell 38% and 70%, while the cane industry fell 4% and 6.5%, respectively. Imports from Mexico increased 130% and 180%, and imports by other countries increased 115% and 228%, respectively, under models 3 and 4.

The purpose of GHG regulations is to reduce global levels of CO_2e emissions. Under model 2, CO_2e emissions from the sugar production for U.S. consumption would decline 3.5%. Under models 3 and 4 that reduction would be 8.4% and 15.9%, respectively. The reductions are small because emissions that are restricted in the United States are transferred to countries that have no restrictions.

Worldwide, the GHG emission reduction is even smaller. Under model 2, the GHG reductions of the sugar industry are 0.20%. Under models 3 and 4, the reductions are 0.47% and 0.90%, respectively.

Impacts of Green House Gas Emission Regulations on the U.S. Sugar Industry

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INTRODUCTION

Sugar is one of the most protected commodities in the world. Protection takes the form of border measures, such as tariffs and quotas, and of direct domestic support, including fixed producer and consumer prices. Only a small proportion of the world's sugar (30%) is traded each year, and a large proportion of that sugar is traded under long-term agreements, quotas, and allotment systems.

Sugar is produced in over 100 countries worldwide. In most years, over 70% of world sugar production is consumed domestically which allowed the development of a large export market. However, a significant share of this trade takes place under bilateral long-term agreements or on preferential terms. Since only a small proportion of world production is traded freely, small changes in production and government policies tend to have large effects on world sugar markets. As a result, sugar prices have been unstable in the world market.

Sugarcane is a perennial grass that is produced in tropical and subtropical climate zones. It matures in 12 to 16 months. Once the cane is harvested, the sucrose starts breaking down. Thus, sugarcane mills are located close to the cane fields to minimize transport costs and sucrose losses. Mills convert sugarcane into raw sugar which is shipped to refineries for further processing. In contrast to raw sugar producing mills, refineries are unconstrained by seasonal production patterns and operate throughout the year. Unlike sugarcane, sugarbeets are an annual crop of temperate climate zones. Because of disease problems, sugarbeets are always grown in crop rotations. Since sugarbeets are bulky and costly to transport, beet processing facilities are located close to production. In contrast to sugarcane, sugarbeets are directly processed into refined sugar. Raw sugar is produced only from sugarcane.

Raw sugar and refined sugar are two different products. They are both traded internationally. Beet sugar producing countries export refined sugar, while cane sugar producing countries export either raw or refined sugar. In recent years, the share of raw sugar in total sugar exports has been about 50%. The conversion between raw sugar and refined sugar is 0.978 units of refined sugar per unit of raw sugar.

The United States House of Representatives passed climate change legislation entitled “The American Clean Energy and Security Act” (ACESA) in June 2009. This bill established a combined efficiency and renewable electric standard (CERES) which requires retail electricity suppliers to utilize 20% of renewable energy by 2020. Senators Kerri and Lieberman introduced a similar bill entitled “American Power Act” in the U.S. Senate. Since the U.S. sugar industry, especially beet sugar production, is energy intensive; the economic impacts of the legislation on the U.S. industry may be significant.

The energy requirements for sugar conversion are different between beet sugar and cane sugar. Coal is used for the energy and heat in beet sugar conversion and natural gas and bagasse are used for cane sugar processing. A typical beet sugar factory will emit about 1 ton of CO_2e per metric ton of sugar while a typical cane mill and refinery will emit about 0.6 ton of CO_2e per metric ton of sugar. By using bagasse, the cane industry will obtain credit for reduced emissions, which will reduce the impact of GHG emission regulations on the industry. GHG emissions in major sugar producing countries are different, but they are generally lower than emissions by beetsugar production and higher than can sugar production in the U.S.

The objective of this study is to analyze the potential impacts of U.S. GHG emission regulations directed towards the U.S. sugar industry. Special attention is given to evaluate U.S. sugar imports when domestic sugar production responds to higher processing costs imposed upon the industry by GHG emission limitations.

The United States produced 7.3 million tons of sugar in 2009: 4.2 million tons of beet sugar and 3.1 million tons of cane sugar (USDA; Sugar and Sweetener Situation and Outlook). The United States imported 2.2 million tons of raw sugar in 2009. The U.S. imports are about 5% of the traded world sugar and approximately 22% of the sugar consumed in the United States. The U.S. sugar imports have declined from 5.3 million tons in the 1970s to 2.2 million tons in 2009. The decline was due mainly to high fructose corn syrup (HFCS) and low calorie sweetener use in soft drinks.

Government support for sugar operates under a nonrecourse loan program that effectively provides a floor price for sugar. Because sugarcane and sugar beets, from which sugar is produced, are not storable, the government provides loans to processors rather than to producers, with sugar as collateral. The U.S. government currently uses domestic marketing allotments to limit the marketing of domestically produced sugar and allows imports of sugar required under international sugar agreements (1.1 million metric tons raw sugar) to maintain sugar supplies sufficient to meet the domestic demand plus an acceptable level of imports. The USDA estimates an import target and uses specific country quotas to achieve the import target level. The United States imports raw sugar from more than 40 countries (USDA; Sugar and Sweetener Situation and Outlook). The major exporters are the Dominican Republic, Brazil, Philippines, and Australia. Each country has an allotment for its sugar exports to the United States. The export allotment has decreased over time. To comply with General Agreement on Tariffs and Trade (GATT), the U.S. government has converted the import quota to a tariff-rate quota.

Under the North American Free Trade Agreement (NAFTA), Mexico currently is allowed to export unlimited quantities of sugar to the United States. Mexico exported 630 thousand metric tons of sugar in 2007, 1.27 million metric tons in 2008, and 490 thousand metric tons in 2009. The U.S.-Central American Free Trade Agreement (CAFTA), which is a free trade agreement (FTA) currently with six Central American countries, provides additional sugar imports of about 250 thousand metric tons, with additional increases of 3,000 metric tons per year.

Development of an Empirical Model

A spatial programming model based on a mathematical programming algorithm was developed to evaluate the impacts of GHG emission restrictions on the U.S. sugar industry. The United States is divided into 10 sugar-producing regions (6 regions for sugar beet and 4 regions for sugarcane). Producing regions in the United States are southeastern Florida, the Mississippi

Delta of Louisiana, south Texas, and Hawaii for sugarcane production; and the Great Lakes (Michigan and Ohio), the Red River Valley (North Dakota and Minnesota), the Northwest (Idaho), the Northern Great Plains (Montana and Wyoming), the central Great Plains (Nebraska and Colorado), and California for sugar beet production. The United States is divided into 34 consumption regions. This model also includes sugar-processing plants for sugar beet and sugarcane and sugarcane refineries.

Mexico is included in the model and allowed to export unlimited amount of sugar to the United States under NAFTA. Mexico is divided into five production regions and one consumption region. Mexico produces sugar from sugar cane. In addition, 40 other sugar exporting countries are included in the model to analyze optimal flows of sugar from those countries to the United States.

The six beet sugar production regions in the United States ship sugar beets to nearby processing plants. Sugar refined at the plants moves to consumption regions. Sugarcane-producing regions ship sugarcane to nearby mills. Raw sugar processed at cane mills and imported from foreign countries is moved to raw sugar refineries. Cane sugar refined at cane sugar refineries moves to consumption regions. Refined sugar imported from foreign countries moves to consuming regions. This study assumes that sugar beets or sugarcane is moved to processing plants by trucks and that sugar is moved from processing plants to consuming regions by railroad.

The objective function of the model is to minimize costs of the U.S. sugar industry through sugar beet and sugarcane production, processing, distribution, and imports to satisfy the domestic consumption. This objective function is optimized subject to a system of linear constraints. The constraints include land available for sugar beet and sugarcane production, processing capacity in each producing region, refinery capacity for raw cane sugar, individual importing country's quota, and domestic sugar consumption in each region.

Mathematical Model

The objective function of the model is mathematically expressed as follows:

(1)
$$Z = \sum_i PC_i\, A_i + \sum_j PC_j\, A_j + \sum_h C_h\, Q_h + \sum_m C_m\, Q_m + \sum_n C_n\, RS_n + \sum_n \sum_n t_{ih} + \sum_h \sum_c t_{hc}\, S_{hc} + \sum_j \sum_m t_{jm}\, Q_{jm} + \sum_m \sum_n t_{mn}\, RS_{mn} + \sum_n \sum_c t_{nc}\, S_{nc} + \sum_e P_e^R\, RS_n + \sum_e P_e\, S_e + \sum_e \sum_p t_{ep}\, RS_{ep} + \sum_e \sum_p t_{ep}\, S_{ep} + \sum_p \sum_c t_{pc}\, S_{pc}$$

where

c = index for consuming regions in the United States and Mexico,
I = index for sugar beet producing regions,
j = index for sugarcane producing regions,
h = index for sugar beet refineries,
m = index for sugarcane mill,
n = index for sugarcane refineries,
e = index for sugar exporting country,
p = index for ports in the United States,
S = quantity of refined beet or cane sugar,

PC = production cost of sugar beets or sugarcane,
A = acreage used to produce sugar beets or sugarcane,
Q = quantity of sugar beets or sugarcane,
RS = quantity of raw sugar produced at mills,
t = transportation cost in shipping sugar beets or sugarcane, raw sugar, and refined sugar from producing regions or processing plants to consuming regions,
C = processing cost of sugar beets or sugarcane at processing plant,
Pr = price of raw sugar,
P = price of refined sugar.

The first two summation terms indicate the total production costs of sugar beet and sugarcane in producing regions. The production costs are calculated by multiplying production cost per acre (PC) by the total acres in production (A). The next three terms represent the total processing costs at sugar beet plants, sugarcane mills, and sugarcane refineries. The next five terms represent transportation costs of sugarbeet or sugarcane from producing regions to consuming regions. The next two terms are the total import costs of raw and refined sugar. The last four terms are transportation costs from exporting countries to domestic consuming regions through ports.

The objective function is optimized subject to the following constraints:

(2) $A_i \leq L_i$

(3) $A_j \leq L_j$

(4) $A_i Y_i = \sum_h Q_{ih}$

(5) $A_j Y_j = \sum_m Q_{jm}$

(6) $\sum_h S_{hc} + \sum_n S_{nc} + \sum_p S_{pc} \geq D_c$

(7) $\sum_i \propto Q_{ih} = \sum_c S_{hc}$

(8) $\sum_j \lambda_1 Q_{jm} = \sum_n RS_{mn}$

(9) $\sum_m \lambda_2 RS_{mn} + \sum_p \lambda_2 RS_{pn} = \sum_c S_{nc}$

(10) $\sum_e RS_{ep} = \sum_n RS_{pn}$

(11) $$\sum_{e} S_{ep} = \sum_{p} S_{pc}$$

(12) $$\sum_{p} \lambda_2 \, RS_{ep} + \sum_{p} S_{ep} \leq QT_e$$

where

- L = maximum arable land for sugar beet or sugarcane production,
- Y = sugar beet or sugarcane yields per acre,
- a = extraction rate of refined sugar from sugar beets,
- λ_1 = extraction rate of raw sugar from sugarcane,
- λ_2 = extraction rate of refined sugar from raw sugar,
- D_c = demand for sugar in each consuming region,
- QT = U.S. sugar quotas.

Equations 2 and 3 are land constraints, indicating that the total land used for sugar beet or sugarcane production should be less than the total land available for the crop. Equations 4 and 5 stipulate that the total sugar beet or sugarcane produced in each producing region should equal the total quantity shipped to processing plants or mills. These constraints do not allow storage of sugar beets or sugarcane at producing regions.

Equation 6 represents demand constraints for sugar consumption in consuming regions, indicating that the total amount of sugar consumed in each consuming region should be obtained from sugar beet processing plants, sugarcane refineries, and foreign exporting countries. Equations 7, 8, and 9 are inventory clearing conditions at sugar beet processing plants, mills, and sugarcane refineries, respectively. Equations 10 and 11 are inventory clearing conditions of imported raw and refined sugar at ports. Equation 12 indicates that total imports from all exporting countries should not exceed the U.S. import quota of sugar.

The Base and Alternative Models

This study is based on one base and three alternative models. The models are stated as follows:

Model 1 is the base model incorporating existing production, processing, and marketing conditions under the current agricultural, trade and environmental policies.

Model 2 is the base model with an additional cost of \$10 per metric ton of CO_2e added to all beet and cane processing plants.

Model 3 is the base model with an additional cost of \$20 per metric ton of CO_2e added to all beet and cane processing plants.

Model 4 is the base model with an additional cost of \$30 per metric ton of CO_2e added to all beet and cane processing plants.

In the base model, the U.S. and world sugar industries are constrained at current production and consumption levels. U.S. imports of sugar are restricted at the current import quota levels. The model also allows the United States to import unlimited amount of sugar from Mexico under NAFTA and 250 thousand tons of sugar from the six countries under CAFTA. Consumption of sugar in each consuming region is fixed at the current levels in the base model.

Models 2, 3, and 4 were developed to evaluate structural changes in sugar production when GHG emission is restricted through either a cap and trade or carbon tax in the United States. In model 2 the carbon tax was set a \$10 per ton of CO_2e. The carbon tax for model 3 was set at \$20 per mt CO_2e and \$30 per mt for model 4. It is assumed that the price of carbon offset in a cap and trade system is equivalent to the taxes. U.S. import restrictions were relaxed in model 2, 3 and 4 as domestic sugar production plus current imports were not sufficient to satisfy domestic consumption.

Data

Transportation costs were divided into five parts: transportation of sugar beet and cane to beet plants and cane mills, respectively, transportation of raw sugar to refineries, transportation of refined sugar to final destinations, transportation of raw sugar from exporting countries to U.S. ports, and transportation of raw sugar from U.S. ports to refineries. The transportation costs of shipping sugar beets and sugarcane to processing plants were assumed to be zero because of the short distances between growing and processing areas.

A rail freight rate function for sugar from processing plants to domestic consuming regions under a double log functional form was estimated with actual rail freight rates from selected sample routes as follows:

(13) $\ln R = -3.86 + 0.583 \ln D + 0.098 \ln W$
(-37.39) (10.80) (6.61)
$R^2 = .65$

where R represents freight rates for sugar shipments from refineries (origin) and domestic consuming regions (destination), D represents distances between the origin and destination, and W represents distances between origin and the nearest water port. The numbers in parentheses indicate t-values of the corresponding parameters.

This equation was also used to estimate the transportation cost of shipping raw sugar from mills to refineries. The rail mileages (D) were calculated using AutoMap Version 6 software by Automap, Inc., and distances between producing region and water access points (W) were obtained from *Rand McNally Road Atlas of the United States and Canada*. Sample rail rate data were obtained from the Waybill data set.

Ocean freight rates from exporting countries to U.S. ports were calculated from the ocean freight rate function, which was estimated with actual ocean freight rates from the selected sample routes. The estimated function is as follows:

(14) $\ln OR = 1.26 + 0.098 \ln OD$
(4.47) (5.54)
$R^2 = .69$

where OR represents ocean freight for raw sugar from export countries to U.S. ports and OD represents ocean mileage between export countries and U.S. ports. The numbers in parentheses indicate t-values of the corresponding parameters.

Ocean mileages were calculated using *The Times Atlas of Oceans* (Times Books Limited). The sample ocean freight rate data were obtained from *Chartering Annual* (Maritime Research Inc.).

The United States imports raw sugar from over 40 countries. Exporting countries export sugar to the United States based on the U.S. import quotas. The import quotas on sugar were obtained from Sugar and Sweetener Situation and Outlook (USDA). The United States currently has a tariff-rate quota system. Each exporting country is allowed to export an allocated quota without a duty but a duty is levied on its exports exceeding the quota into the United States. The United States imported 2.52 million tons of sugar in 2009, 1.55 million tons through the tariff rate quota system, 0.54 million ton from Mexico and 0.43 million tons through other programs.

Most of the U.S. sugar data was obtained from the ERS in various issues of Sugar and Sweeteners Outlook. CO_2e were obtained from LMC for the cane industry and from U.S. Beet Sugar Association for the sugar beet industry. Processing costs for the cane industry were obtained from LMC and processing cost for the beet industry was obtained from U.S. Beet Sugar Association. The location and capacity of the Mexican sugar industry were obtained from ERS. Acres available for production and yield data were obtained from the Sugar and Sweetener Situation and Outlook Year Book 2009 (USDA). Refinery capacities for North American refineries were obtained from U.S. Beet Sugar Association. Sugar import data and sugar prices were obtained from Sugar and Sweetener Situation and Outlook (USDA).

The USDA divides the United States into five regions for sugar distribution. Total demand for sugar in each consuming region in the United States is calculated by multiplying the per capita consumption of sugar by the population within each consumption region. Per capita consumption of sugar is calculated by dividing the total consumption by the U.S. population. The U.S. population was obtained from the U.S. Department of Census. The total sugar consumption was obtained from the Sugar and Sweetener Situation and Outlook (USDA).

Results

Production and Imports

Table 1 presents the total of beet and cane sugar produced in the United States, Mexico and the rest of the world under models 1 through 4. The total amount of sugar produced in the United States is 7.2 million metric tons in model 1; 4.1 million tons from sugar beets and 3.2 million from sugar cane. The United States imported 276 thousand metric tons from Mexico and 1.1 million metric tons from others.

Table 1. Sugar Production in the U.S. and Other Countries Under Models 1 Through 4				
	Model 1	Model 2	Model 3	Model 4
	1,000 metric tons raw sugar			
U.S. Beet	4,051	3,366	2,507	1,209
U.S. Cane	3,221	3,134	3,103	3,015
Mexico	276	485	636	774
Others	1,131	1,693	2,432	3,680
Total	8,679	8,678	8,678	8,678

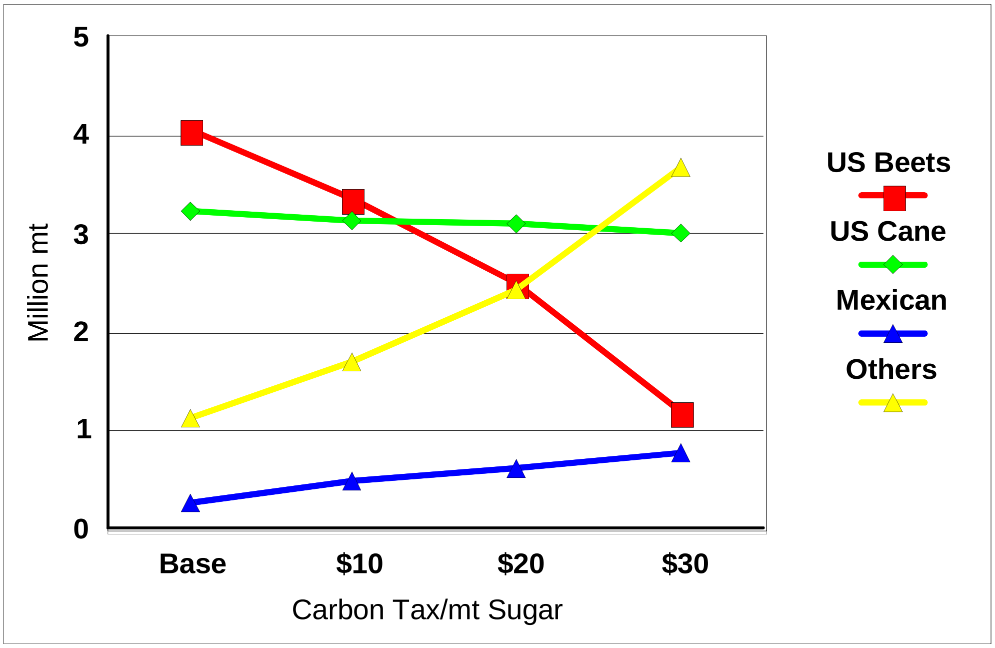

Figure 1. U.S. Sugar Production, Mexican Exports and Other Countries Exports, Various Scenarios

Under model 2 with a $10 carbon tax, the United States produced 6.4 million metric tons of sugar, a reduction of 8.2% from model 1. Beet sugar production fell by 16.8% while cane sugar production fell by 2.7%. Imports from Mexico increased to 485 thousand metric tons or 76% from model 1. Sugar imports from other countries increased 50% from model 1. When the carbon tax was increased to $20 per metric ton, U.S. sugar production decreases to 5.6 million metric tons, a 22% reduction from model 1 and a 14% reduction from model 2. U.S. beet sugar production was reduced to 2.5 million metric tons, a 38% reduction from model 1, and U.S. cane sugar production was reduced to 3.1 million metric tons, a 4% reduction from model 1. Mexican exports increased to 636 thousand metric tons and U.S. imports from other countries increased to 2.4 million metric tons. In model 4, U.S. sugar production fell to 4.2 million metric ton which is a 56% reduction from model 1. U.S. beet sugar production fell to 1.2 million metric ton, a 70% reduction from model 1, while U.S. cane sugar production fell to 3.0 million metric tons, a 6.5% reduction from model 1. The United States imported 833 thousand metric tons of sugar from Mexico and 3.7 million metric tons from other countries. The reasons for a sharp reduction in beet sugar production compared to cane sugar production is that carbon emissions in processing sugar beet are much higher than cane. Sugar beet processing plants are much more energy intensive relative to cane sugar processing and use coal rather than natural gas and bagasse.

Figure 1 clearly shows decreases in beet and cane sugar production in the United States and increases in cane sugar production in other countries under alternative carbon taxes. The sharp decreases in U.S. domestic production of sugar in replaced with sugar imports from Mexico and the rest of the world as carbon tax increases from zero to $30/ton of CO_2e.

<u>Carbon Footprint of U.S. Sugar Consumption</u>

The goal of a cap and trade or carbon tax system is to reduce GHG emissions that are released to the atmosphere. CO_2e were estimated for the four models to evaluate the effectiveness of the program. Since it was assumed that retail sugar prices did not change, all costs were borne by the producers and consumption remained the same under all scenarios. Therefore the amount of sugar consumption did not change, only its source. Table 1 shows the calculations for GHG emission under the various scenarios. The second column of Table 2 presents CO_2e emission from sugar processing. The U.S. beet sugar industry emits 1.16 tons of CO_2e per ton of refined sugar, while the cane sugar industry emits 0.57 tons of CO_2e per ton of refined sugar. This implies that if the United States restricts GHG emission by imposing a carbon tax or implementing a cap the trade system, the burden of the restriction in the beet sugar industry is much larger that the cane sugar industry. In addition, CO_2e emission in Mexico and other countries are higher than from U.S. cane sugar processing companies. Therefore, unless other sugar exporting countries restrict GHG emission, the regulation in the United States would not significantly reduce CO_2e emissions.

Table 2. CO_2e Emissions From Sugar Processing For U.S. Sugar Consumption

		Model 1	Model 2	Model 3	Model 4
	CO_2e(ton)/ ton sugar	CO_2e emissions (1,000 metric tons)			
U.S. Beet	1.16	4,699	3,905	2,908	1,402
U.S. Cane*	.570	1,836	1,786	1,769	1,718
Mexico	.893	246	433	568	691
Others	.692	783	1,172	1,683	2,546
Total		6,774	6,508	6,225	5,332
Percent change from Model 1			-3.5	-8.4	-15.9

*Florida will receive a CO_2e credit for renewable electricity use reducing CO_2e to zero.

GHG emissions, as indicated in Table 2, from the U.S. sugar beet industry was reduced by 70% between model 1 and model 4, while the GHG emissions for the sugar cane industry were reduced by 6%. GHG emissions for Mexican sugar industry increased under models 2, and 3 because Mexico increased sugar exports to the United States under those scenarios. GHG emissions for other countries increased 225% because of increased sugar exports to the United States. The total net impact was a 3.5% reduction in GHG emission for the sugar that the United States consumed between model 1 and model 2. Under model 3 and 4 the reduction was 8.4% and 15.9%, respectively. Figure 2 shows the same information graphically. Since carbon emissions for beet sugar are higher than cane sugar and sugar imported from foreign countries (Table 2), beet sugar consumption is replaced with cane sugar and imported sugar as the price of carbon credits increase from $10 per ton to $30 per ton.

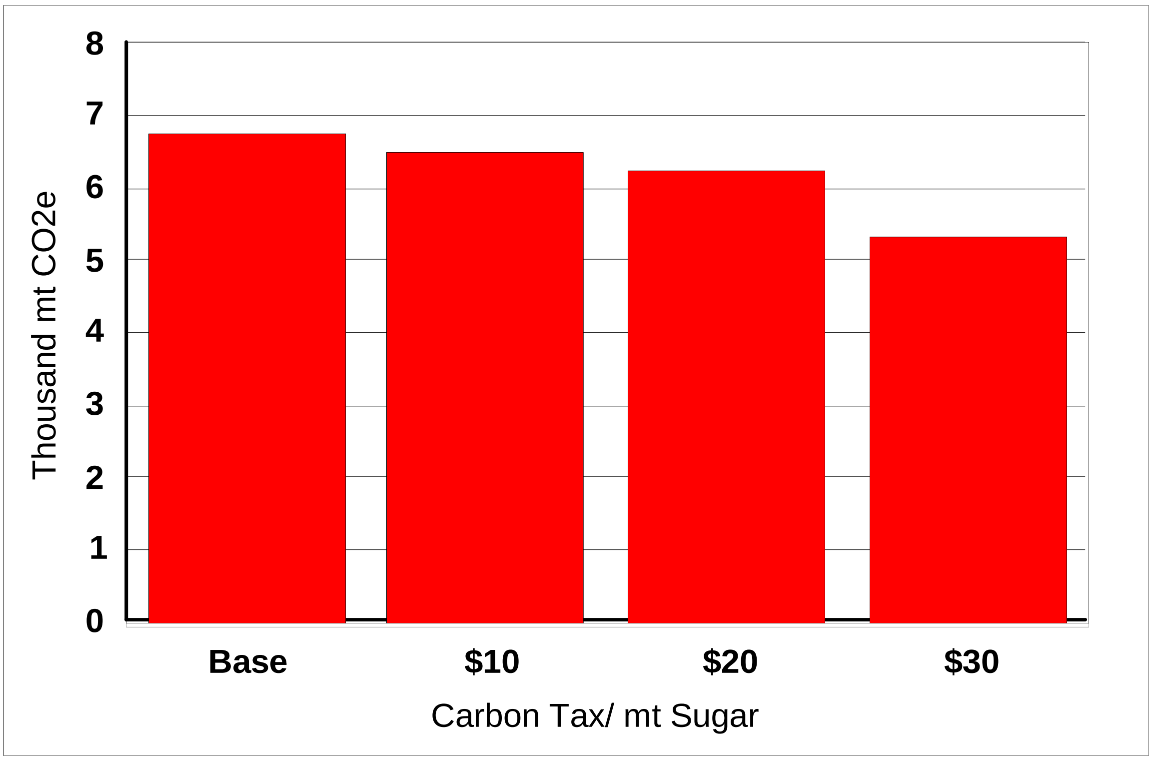

Figure 2. GHG Emissions For Sugar Processed for U.S. Consumption

When GHG emissions are regulated in the United States, while unregulated in other countries, domestic emission is reduced but most of that reduction is replaced by emissions from other countries. A carbon tax of $10 per ton of CO_2e (model 2) would reduce world wide CO_2e by 268 thousand metric tons annually. When compared to total GHG emissions of the world sugar industry; 134 million metric tons of CO_2e in 2009, the percent decrease is 0.20% (Figure 3). The percent reduction for model 3 and model 4 is 0.47% and 0.90%, respectively.

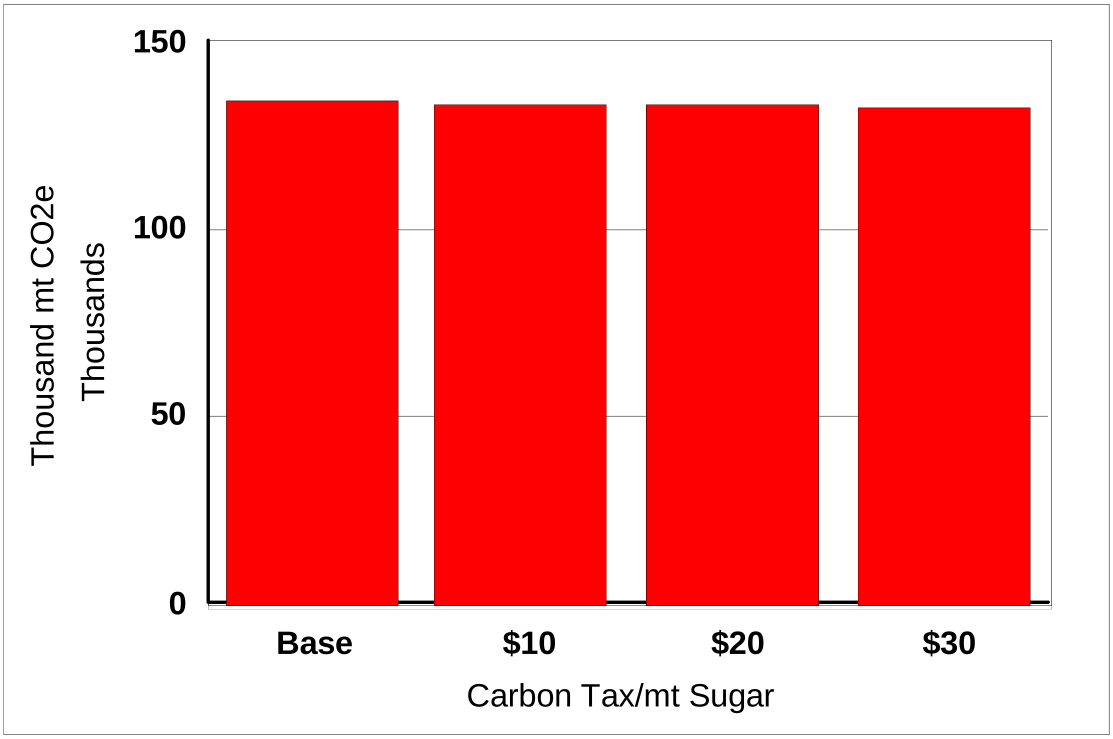

Figure 3. World GHG Emissions of the World Sugar Industry Under Various Scenarios

Economic Impact of GHG Regulations

The reduction in U.S. sugar production will have an economic impact on both the sugar industry and the overall economy. Table 3 shows the economic impact of the reduction of sugar production under the various scenarios. An alternative use for the land is included as land removed from sugar beet and cane production will be used as the next best alternative. For this calculation it is assumed the equal shares of corn, soybeans and wheat are planted on the acres released when sugar beets and sugar cane are no longer produced. Thus the net revenue loss in the beet sugar industry is calculated by subtracting revenue gain in alternative crops from the revenue loss in the reductions in the sugar beet production. The revenue loss and revenue gain are calculated as

(15) $RL_i = (Q_i - Q_{base}) * P^s$

where RL_i represents revenue loss resulting from decrease in sugar beet production in model i, RG_i = is revenue gain from production of alternative crops such as wheat, corn, and soybeans, Q_i is production of sugar beet in model i, Q_{base} is production of sugar beet in the base model, Q^a_{ji} is the quantity of alternative crop j produced in model i and P_j is the price of crop j. the net revenue loss in sugar beet industry in models 2, 3, and 4 are $NRL_i = RL_i - RG_i$, i=2,3,4. The same procedure is used to calculate the net revenue loss for the cane sugar industry.

The reductions in sugar productions in models 2, 3, and 4 are calculated from Table 1. The reductions in beet sugar production are 685, 1,544, and 2,842 million metric tons raw value in models 2, 3, and 4, respectively, compared to model 1 (base model). Similarly, the reduction in cane sugar productions are 78, 118, and 206 million metric tons raw value. The total revenue losses in sugar cane and sugar beet industries are calculated by multiplying the reduced production by the recent 3 month average wholesale raw sugar price, $694 per ton. Table 3 presents the revenue loses in the sugar beet and sugar cane industries in the United States.

Table 3. Economic Impact of GHG Regulations Under Alternative Scenarios

Revenue Reduction From Base Model

	Model 2	Model 3	Model 4
	------------------------------$1,000-------------------------------		
Sugar Beets	475,390	1,071,536	1,972,348
Sugar Cane	60,378	81,892	142,964
Total Reduction	535,768	1,153,428	2,115,312
Alternative Crop Income	78,823	170,487	307,803
Net Economic Impact	456,945	982,941	1,807,509

A total revenue loss of $536 million would occur in the U.S. sugar industry under model 2 assuming a raw sugar price of $694/ton. With models 3 and 4 the revenue loss would be $1.2 billion and $2.1 billion, respectively.

It is assumed that alternative crop are wheat, corn, and soybeans in the sugar beet producing region and no alternative crops in Florida but cotton in Louisiana and Texas. It is also assumed that yields are 140 bushels per acre for corn, 35 bushels per acre for soybeans and 50 bushels per acre for wheat. Based on recent average crop prices, wheat price was assumed to be $5.00 per bushel, Soybean, $10.00 per bushel and corn $3.00 per bushel. The crops would generate $79 million, $170 million and $308 million, respectively, under the three alternative models. Value added activities are not include for the alternative crops because the extra crop production would probably be exported and no further processing would occur. The net reduction in the revenue in the U.S. sugar industry would be $457 million under model 2, $983 million under model 3, and $1.8 billion under model 4. The carbon emission reductions for those models are 266 thousand mt, 549 thousand mt, and 1.4 million mt under models 2, 3, and 4, respectively.

The reduction in the net revenue per ton of CO_2e is $1,718 with a carbon price tax of $10 per ton (model 2) in the U.S. sugar industry. The reductions in the net revenue are $1,790 per ton of CO_2e with carbon price tax of $20 per ton (model 3) and $1,285 per ton of CO_2e with a carbon price tax of $30 (model 4). Average reduction in the revenue per ton of CO_2e is $1,598. The reason for high cost of carbon reduction in the U.S. sugar industry is that sugar production is moved to foreign countries where GHG emissions are not regulated. As a result, the reduction in GHG emissions for U.S. sugar consumption is not significant, but sugar production is reduced significantly in the U.S. beet sugar producing regions.

Conclusion

The U.S. sugar industry, especially the sugar beet industry, is facing an unknown future. GHG regulation could increase production costs which would impact local growers.

If the United States regulates GHG emissions in processing sugar, substantial production decreases will occur in the U.S. sugar beet industry, while the U.S. sugar cane industry will be impacted slightly. With a carbon tax of $10 per ton of CO_2e, U.S. sugar beet production could be reduced 17%, while U.S. sugar cane production could be reduced 3%. Under model 4 with carbon tax of $30 per ton, sugar beet production could be reduced by 70% and sugar cane production could be reduced by 6%.

This study shows that regulations directed towards only domestic industries will not achieve the desired goal of reducing GHG emissions. GHG emissions reductions in the United States will be replaced by GHG increases in other parts of the world. This highlights a concern of unilateral regulations in a country. Regulations in one country will just move the problem to another country without significantly reducing GHG emissions. Since GHG emissions is a global concern it should be addressed globally. Another alternative is a tax on sugar when it is imported from an exporting country where GHG emissions are not regulated. This tax may protect the domestic industry but the costs would be transferred to consumers.

The cost to the U.S. sugar industry would be substantial with GHG emission regulations. Carbon emission reduction would cost the economy about $1,600 in direct economic activity per ton of CO_2e reduction.

References

Auto Map, Inc. 2006. "AutoMap Version #6." Phoenix, Ariz.

British Sugar. Website http://www.britishsugar.co.uk.

LMC International GHG Calculation For Selected Sugarcane Industries: Key finding for U.S. Sugar Beet Association. November 2009. Oxford, UK.

Rand McNally, Inc. 1978. *Rand McNally Road Atlas of the U.S. and Canada*. San Francisco, Calif.

Time Books Limited. 1983 *The Times Atlas of Oceans*. Von Nostrand Reinhold Company, Inc., New York.

United States Department of Agriculture-ERS. *Sugar and Sweetener Yearbook.* 2009. Washington, D.C.

United State Department of Agriculture-FAS. Production, Supply and Demand website. Washington, D.C.

United States Department of Census. 2009. *Statistical Abstract of the United States*. Washington, D.C.

U.S. Beet Sugar Association. Personal communication. Elin Peltz. May 10, 2010. Washington D.C.